Subiteration-preconditioned GMRES for fluid-structure interactions

C. Michler, **E.H. van Brummelen** and **R. de Borst**

Faculty of Aerospace Engineering
Delft University of Technology
P.O. Box 5058, NL-2600 GB Delft, The Netherlands
C.Michler@LR.TUDelft.nl, E.H.vanBrummelen@LR.TUDelft.nl, R.deBorst@LR.TUDelft.nl

The numerical solution of fluid-structure interaction problems is of great relevance in many engineering disciplines. Monolithic solution methods typically employ subiteration, the sequential solution of fluid and structure with asynchronous enforcement of the interface conditions; this process is repeated until convergence. Although for certain problems the subiteration method is an excellent solver, it converges only slowly or even diverges for problems with large computational time steps or large fluid-to-structure mass ratios. Ref. [1] propounds nonnormality of the subiteration operator as a prinicipal cause of failure.

We consider a model fluid-structure interaction problem and investigate convergence difficulties which occur for large computational time steps. We show that subiteration convergence deteriorates with increasing time-step size and eventually the subiteration diverges. Due to nonnormality the iterative process can exhibit a transient behaviour during which the error can grow over a finite number of steps by several orders of magnitude before it eventually decreases, see Fig. 1. This transient error growth renders convergence slow and might even cause the computation to fail before asymptotic convergence sets in.

To moderate the initial error growth and improve convergence of the subiteration method for nonnormal problems, we investigate the application of under-relaxation and GMRES acceleration. GMRES constructs the search directions from intermediate iterates which have been generated by successive subiterations. Therefore our proposed strategy is cheap and easily implemented in existing codes which use subiteration as a solver. The subiteration method can then be considered as a preconditioner to the GMRES method. We demonstrate that convergence difficulties can be nicely mitigated by under-relaxation and GMRES acceleration, see Fig. 1. Convergence is monotone and requires much fewer iterations. This approach allows to treat larger ranges of problem parameters efficiently and achieves convergence even for problems in which standard subiteration diverges. This demonstrates that the proposed strategy substantially improves the robustness and efficiency of the standard subiteration method.

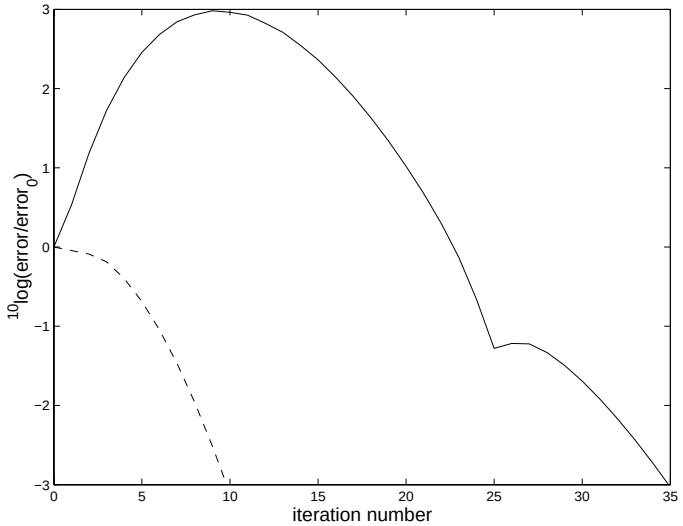

Figure 1: Convergence of subiteration (—) and under-relaxation with GMRES (– –).

References

[1] E.H. van Brummelen, "Convergence of successive approximation for a free-boundary problem in fluid-structure interaction", *Moving Boundaries 2003: Proceedings of the Seventh International Conference* , Santa Fe, New Mexico, USA, 4-6 November 2003. WIT Press, Wessex Institute of Technology, UK. (Submitted for publication). Preprint available at : `http://www.em.lr.tudelft.nl/~brummelen/publications`